

CLAIMS:

1. A system for the accurate determination of the position of an underwater vehicle comprising:

a sea borne position marker having a known position;

at least one underwater vehicle acoustically coupled to the ^{sea borne} {single} position marker;

a system observer comprising a state updater for predicting the underwater vehicle's position, $Pp(n)$, based on a past estimate of the underwater vehicle's position, $Pe(n-1)$ and an estimate of the underwater vehicle's velocity over the sea bottom, and a maximum likelihood estimator, to estimate the underwater vehicle's position ($MLE(n)$), utilizing measured ocean depth at the underwater vehicle's position, bathymetry data and the underwater vehicle's predicted position based on a past estimate of the underwater vehicle's position and an estimate of the underwater vehicle's velocity over the sea bottom, $Pp(n)$ in a single point position match; *unclear*

an extended Kalman filter that takes ^{the} state updater's estimate of the underwater vehicle's position, $Pp(n)$, and the maximum likelihood estimator's estimate of the underwater vehicle's position, $MLE(n)$, and computes a linear Kalman filter position estimate at time (n) , $KPAT(n)$; *define?*
and

→ a range corrector that utilizes the linear Kalman filter position estimate at time (n) , $KPAT(n)$, ^a sea borne position marker, and a measured slant range from the at least one submersible vehicle to the sea borne position marker and computes a final estimate of the at least one ^{underwater} submersible vehicle's position.

2. A system for the accurate determination of the position of an underwater vehicle comprising:

a sea borne position marker having a known position;

means for acoustically coupling at least one underwater vehicle to the sea borne position marker;

means for predicting the at least one underwater vehicle's position, based on a past estimate of the underwater vehicle's position and an estimate of the underwater vehicle's velocity over the sea bottom;

means for estimating the underwater vehicle's position utilizing measured ocean depth at the underwater vehicle's position, bathymetry data and the underwater vehicle's predicted position in a single point position match;

means for computing an estimate of the underwater vehicle's position based on the prediction of the at least one underwater vehicle's position based on vehicle dynamics and the

estimated underwater vehicles position based on ^{the} measured ^{ocean} depth and ^{the} bathymetry data;

means for computing a corrected estimate of the at least one ^{underwater} (submersible) vehicle's position that utilizes the estimate of the underwater vehicle's position, and a measured slant range from the at least one ^{underwater} (submersible) vehicle to the sea borne position marker.

3. The system of claim 2, wherein said sea borne position marker having a known position comprises an acoustic ranging device mounted on a buoy.

4. The system of claim 2, wherein said sea borne position marker having a known position comprises an acoustic ranging device mounted on the sea floor.

5. The system of claim 2, wherein said sea borne position marker having a known position comprises an acoustic ranging device mounted on a vessel.

6. The system of claim 2, wherein said means for acoustically coupling comprises an acoustic transponder.

7. The system of claim 2 wherein said means for predicting the at least one underwater vehicle's position, based on a past estimate of the underwater vehicle's position and an estimate of the underwater vehicle's velocity over the sea bottom comprises

8. A system for the accurate determination of the position of an underwater vehicle comprising:

a system observer subsystem having a state velocity update module,

a terrain matching module, ^{function}

means for generating a prediction of the terrain matching module's performance; and

a constrained extended Kalman filter subsystem having a steady state extended Kalman

filter,

a non-linear constraint module, ^{function} and

a state predictor;

wherein the system observer ^{subsystem} integrates bathymetry data corresponding to the area of the ^{underwater} (submersible) vehicle, with the ^{underwater vehicle} vessel's measured ocean depth, the vessel's predicted state, the vessel's measured velocity into a terrain based state estimate, ^{and} a final predicted state, the Kalman filter takes the terrain based state estimate, the final predicted state, ^{the} measured slant range and ^a the location of the known point and computes ^{the} final estimate of the vessel's position and a prediction of the vessel's position at the next time step. ^{underwater vehicle}

9. The system of claim 8 wherein said state velocity update module receives the vessel's ^{underwater vehicle} predicted state using all of the information before the current time step, and the vessel's measured velocity and computes the vessel's final predicted state.

10. The system of claim 8 wherein said terrain matching module receives the bathymetry data, a measurement of the ocean's depth at the vessel's position and the vessel's final predicted state and computes the terrain based state estimate with a single point position match.

11. The system of claim 8 wherein said means for generating a prediction of the ^{terrain matching module's} underwater vehicles spatial performance comprises a performance prediction module which receives the bathymetry data and generates a spatial-based performance estimate.

12. The system of claim 8 wherein said ^{extended} steady state ^{underwater vehicle} Kalman filter receives the vessel's final predicted state and a ^{the} terrain based state estimate from said system observer subsystem and computes the linear filter's state estimate.

13. The system of claim 8 wherein said non-linear constraint module receives the underwater vehicle's measured slant range and location of the known point, the ^{underwater vehicle} vessel's final predicted state form the system observer ^{and} and the linear filter's state estimate and generates an estimate of the vessel's final state.

14. The system of claim 8 wherein said state predictor receives the vessel's final estimated state form the non linear constraint module and generates a prediction of the vessel's state at the next time step using the data generated for the current time step.

15. A method for the accurate determination of the position of at least one underwater vehicle comprising:

acoustically coupling at least one underwater vehicle to a sea borne position marker having a known position;

predicting the at least one underwater vehicle's position, based on a past estimate of the underwater vehicle's position, and an estimate of its velocity over the sea bottom;

estimating the underwater vehicle's position utilizing measured ocean depth at the underwater vehicle's position, bathymetry data and the underwater vehicle's predicted position in a single point terrain match;

computing a estimate of the underwater vehicle's position based on the prediction of the at least one underwater vehicle's position based on vehicle dynamics and the estimated underwater vehicle's position based on ^{ocean depth} ^{and} bathymetry data with an extended Kalman filter;

computing a corrected estimate of the at least one ^{underwater} submersible vehicle's position that utilizes the estimate of the underwater vehicle's position and a measured slant range from the at least one submersible vehicle to the sea borne position marker whose position is known.

16. A computer for the analytic determination of the position of at least one underwater vehicle acoustically coupled to a position marker having a known position using bathymetry data, positioning data, the underwater vehicle's velocity over the sea bottom, and a slant range from the position marker comprising:

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a computer for computing

- (a) a prediction of the underwater vehicle's position, $P_p(n)$, based on a past estimate of the underwater vehicle's position, $P_e(n-1)$ and an estimate of the underwater vehicle's velocity over the sea bottom with a state updater,
- (b) an estimate of the underwater vehicle's position ($MLE(n)$), utilizing measured ocean depth at the underwater vehicle's position, bathymetry data and the underwater vehicle's predicted position based on a past estimate of the underwater vehicle's position and an estimate of the underwater vehicle's velocity over the sea bottom, ($P_p(n)$) in a single point position match with a maximum likelihood estimator,
- (c) a linear Kalman filter position estimate at time (n), $KPAT(n)$ using the state updater's estimate of the underwater vehicle's position, $P_p(n)$, and the maximum likelihood estimator's estimate of the underwater vehicle's position, $MLE(n)$ with an extended Kalman filter, and
- (d) a final estimate of the at least one ^{underwater} submersible vehicle's position with a range corrector that utilizes the linear Kalman filter position estimate at time (n), $KPAT(n)$, a sea borne position marker, and a measured slant range from the at least one submersible vehicle to the sea borne position marker.

underwater